Navigation Nugget

New chip-scale atomic clock plus GPS receiver transforms navigation

By Randy Rollo

The Global Positioning System and Navigation Systems Division (Code 231) of the Space and Naval Warfare Systems Center (SSC) San Diego is incorporating a chip-scale atomic clock (CSAC) into a new GPS receiver design that they are calling the "Navigation Nugget."

SSC San Diego's Central Engineering Activity (CEA) Laboratory received the first chip-scale atomic clock from the National Institute for Standards and Technology (NIST) Laboratory last year and will start characterizing a new CSAC from Symmetricom Corp. in April.

Navigation Nugget project manager Randy Rollo said, "The Navigation Nugget is the first GPS receiver in the world to incorporate a CSAC. This is a major milestone that is expected to transform military GPS receiver designs for the future years to come.

"Many battlefield assets, [including the] Global Information Grid-enabled networks and the nation's infrastructure, rely heavily on GPS for timing information and synchronization. GPS is a highly accurate positioning, navigation and timing [PNT] system, but susceptible to interference and disruption."

Navigation Nugget Description

The "Nugget" is the convergence of a chip-scale atomic clock combined with a deeply integrated microelectromechanical systems (MEMS) inertial measurement unit and a GPS M-code software receiver. MEMS is the integration of mechanical elements, sensors, actuators and electronics on a common silicon substrate through microfabrication technology. While the electronics are fabricated using integrated circuit process sequences, the micromechanical components are fabricated using compatible micromachining processes that selectively etch away parts of the silicon wafer or add new structural layers to form mechanical and electro-mechanical devices.

Technology

The Navigation Nugget creates a robust PNT sensor suite capable of operating in impaired and threatened GPS environments. It will help ground forces in canopy or jammed environments and improve vertical accuracy in differential GPS. Therefore, it benefits antenna systems using beam forming techniques and programs, like the Joint Precision Approach and Landing System, that have stringent vertical requirements. The ability to act as a platform precise timing source is also beneficial to warfighter communications and networks.

The first chip-scale atomic clock evaluated was developed by NIST through the Defense Advanced Research Projects Agency (DARPA) Micro-Electro-Mechanical Systems (MEMS) Program Office. SSC San Diego is the first to incorporate CSAC into the breakthrough GPS receiver design.

The Navigation Nugget core technology fuses a GPS software defined receiver (SDR) with an inertial measurement unit (IMU), all synchronized by the onboard atomic clock to create a robust PNT sensor suite. (See Figure 1 for a diagram of the Navigation Nugget design.)

The initial design objective is the definition, specification and demonstration of an atomic clock's precise time converged with an integrated IMU and the new military GPS (M-code) SDR. The

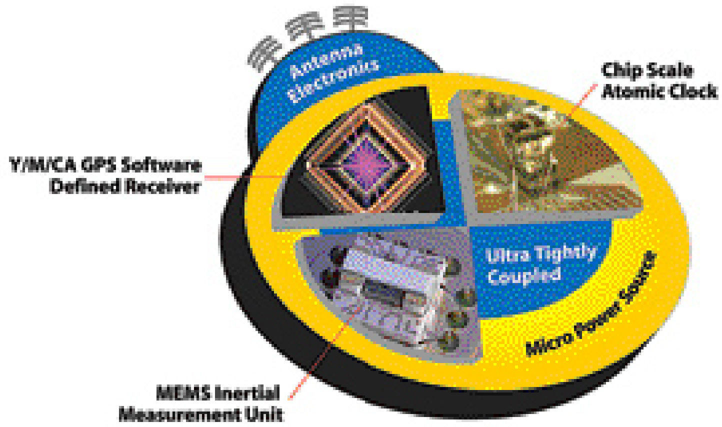

Figure 1. Diagram of the Navigation Nugget.

Navigation Nugget's development cycle is bifurcated into MEMS technology and existing scale components until MEMS technology is fully mature. This allows measurement and validation of the Navigation Nugget's design and benefits and enables larger platforms to receive the improved PNT capability more rapidly. It also allows networks to obtain another source of highly accurate timing. Rollo stated that a field testable prototype could be developed in about 18 to 24 months.

Development and testing is performed in the GPS Central Engineering Activity Lab using a newly developed M-code software defined receiver, inertial navigation system (INS) equipment and atomic clocks. The CEA Lab provides modernized and legacy GPS signal environments for component and system evaluations. It also provides dynamic test scenarios for measuring and validating the Navigation Nugget in a challenging environment in jamming scenarios.

Using the MEMS inertial measurement unit, the Navigation Nugget can continue to operate during periods of GPS signal disruption in urban canyon areas. When the Navigation Nugget begins to receive signals again, it can quickly reacquire satellite linkage because the chip-scale atomic clock will maintain precise time allowing higher probability of fast reacquisition.

Additionally, the Navigation Nugget's flexible receiver design allows integrating signals of opportunity to further enhance indoor navigation. New precise-time-aided algorithms include Code 231's particle filtering accelerator effort for further navigation solution accuracies.

SSC San Diego is using the existing Alpha Data card with a Xilinx field programmable gate array receiver testbed to provide flexibility in developing nugget-based systems. Code 231 engineers are starting with inertial measurement unit simulations to test integration techniques that allow a phased introduction of technology such as particle filtering to further tie the system design together. This spiral engineering process, shown in Figure 2, is designed to accelerate development, reduce government costs and enable rapid analysis.

Goals

The operational payoff goal is to develop a highly resilient positioning navigation and timing system that takes advantage of a chip-scale atomic clock in an integrated configuration. This can be applied to human assets, networks and other platforms as necessary. The goals are:

Figure 2. Diagram of the Navigation Nugget Development Timeline.

• Improve jamming resistance, integrity monitoring, anti-spoofing and fault detection;

•Direct Y-code and M-code acquisitions through "precise-time aiding";

•Accelerate reacquisitions, especially within challenging environments;

• Modify Kalman filter architecture using precise time aiding, i.e., add particle filtering;

•Improve vertical accuracy for coupled beam-forming antenna integrations, Joint Precision Approach and Landing System, etc.;

•Reduce the number of satellites required for an accurate PNT solution;

•Investigate antenna electronics and micropower (fuel cell) integrations.

Battlespace Benefits

The development of the Navigation Nugget allows warfighters and warfighting platforms to navigate in waters and terrains that can be unattainable with current standalone GPS receivers. It allows warfighters to navigate with less interruptions and faster reacquisitions when GPS signal degradations occur. Further, the Navigation Nugget's precise-time feature enables battlefield synchronization for communication systems and networks.

In future platform integrations, the "Nugget's" ubiquitous positioning, navigation and timing sensor suite will enable net-centric synchronization for command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR) systems.

The bifurcated approach to spiral engineering of the Navigation Nugget, developed with MEMS technology, satisfies the size, weight and power requirements of unmanned vehicles and dismounted Soldiers.

The future is here today!

Randy Rollo works in the Global Positioning System and Navigation Systems Division of SSC San Diego as the project manager for the Navigation Nugget.

CHIPS

Matt Nicholson (left), senior engineer, and Randy Rollo, project manager, sitting behind the chip-scale atomic clock test fixture in SSC San Diego's Central Engineering Activity Laboratory.